Vegetational Analysis with Skylab-3 Imagery

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Introduction

The overall objective of this study was to define the extent to which SKYLAB 3 imagery could be used in interpreting vegetational classes located in northeastern North Carolina. Additionally, a demonstration of the limits of usefulness of the imagery to a semi-skilled photo-interpreter in making a vegetational map was another objective. Perquimans County, North Carolina, was used as the test site. This particular investigation has demonstrated that it is possible to recognize and map at an acceptable level of accuracy the several species chosen for study.

Past investigators have found color infrared photography to be superior to standard color for vegetational analysis. Wood (1953) applied this then new film technique to an aerial forest survey and obtained better results than with color film. Studies of marshland by Anderson (1968) indicated that color infrared photography was superior for differentiation of vegetative types within an estuary. Thamon and Sanger (1971) used many remote sensing techniques in analyzing agricultural crops. Their results indicated that color infrared photography was the best sensing means for identifying crops. Many other uncited studies also record the usefulness of color infrared photography for vegetational analysis.

The present investigation was conducted in the northeastern portion of North Carolina because of the presence of diverse coastal environments and because of the nature of the crops grown in this region. Population is relatively low in this region, and few botanical studies have been made. In addition, various types of vegetation and crops occur in relatively large acreage units so that the need to recognize small plots is minimal.

Method

The objective of this study was the evaluation of SKYLAB photography as a vegetational mapping tool for three coastal vegetation classes in terms of species composition and distribution in northeastern North Carolina. Color infrared photography, Roll 27 and Frames 29-31, SKYLAB 3 imagery proved to be the most useful format for this study. Figure 1 is a map of the northeastern region of North Carolina. Three sites (1,3,5) were designed as control sites, and their vegetational composition was determined by on-site inspections. Three other experimental sites (2,4,6) were chosen, and the SKYLAB photographs interpreted on the basis of the results from the control sites. All sites had an area of about one square mile.

Field studies were made of three control sites to correlate vegetation with its photographic response. Three experimental sites believed to possess the same vegetation class as the control areas were examined under a stereo binocular microscope. After the experimental locations had been analyzed from the photography, ground examinations were performed to verify the interpretation and the degree of accuracy.

The accuracy of the photographic interpretation was determined by the following steps. A scaled drawing was first constructed from a USGS topographic map enlargement. Next, the percentage of each category determined from the photographic interpretation was determined using two methods. The grid overlay method involved the use of a dot grid consisting of one hundred dots per square inch on a transparency. Each category was determined by counting the number of dots found within its boundaries, and this number was then divided by the total number of dots in the whole area to obtain a

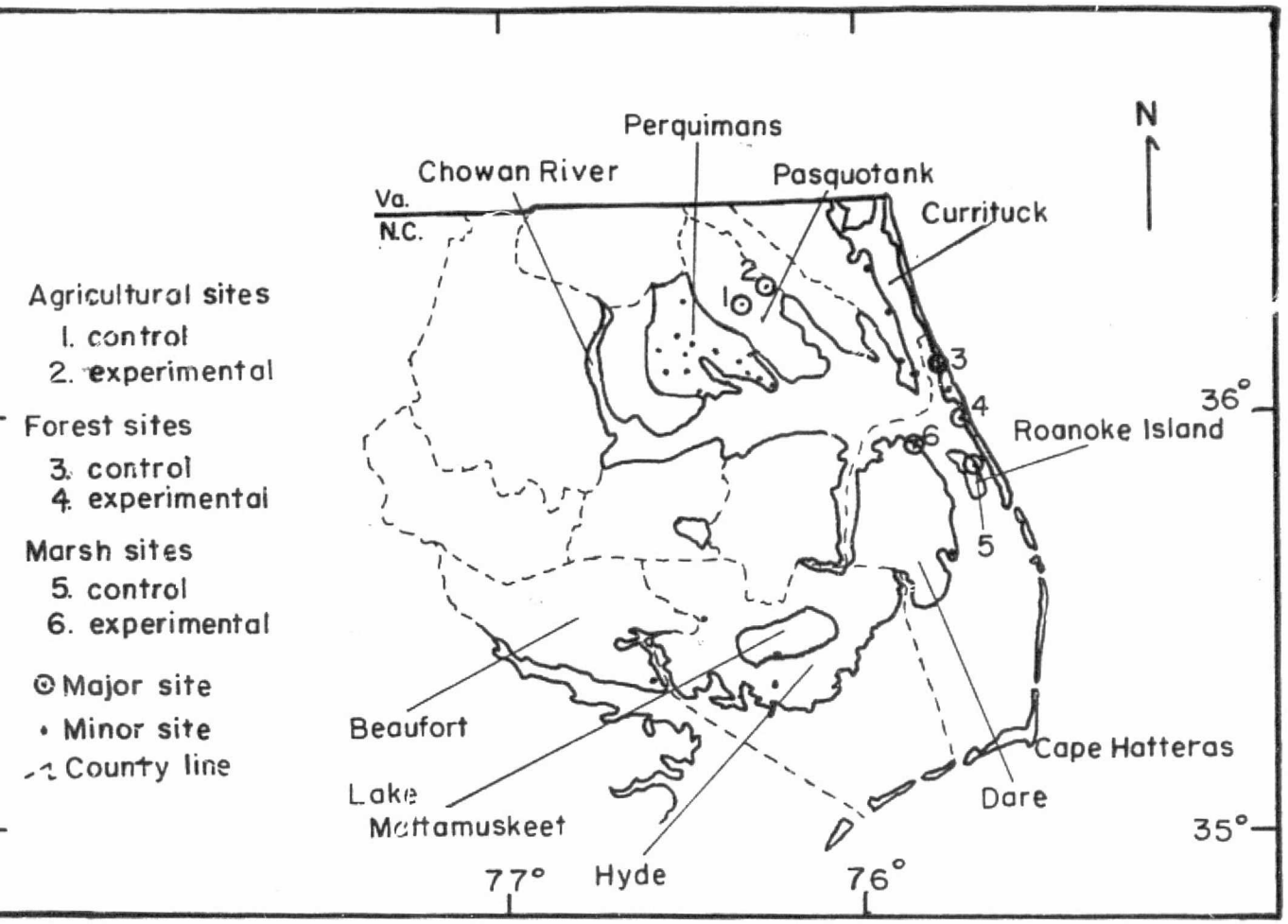

Figure 1. Map of study sites

percentage. The second method was the weight apportioning method. The areas of the different categories were outlined on a scale drawing made on paper of uniform thickness and specific gravity. Each category was then weighed on a balance sensitive to .00001 mg and divided by the total weight of the area in question to determine the appropriate percentage. It was found that both methods obtained similar results but with less time and greater accuracy prevailing when the weight apportioning method was used on large areas.

Field studies were conducted in the experimental areas to verify the photographic interpretation. Corrections were made on the scaled drawings and the misinterpreted areas were subtracted from the total area to obtain the percentage of accuracy.

Six test sites were divided among three vegetation classes: agricultural, maritime forest, and salt marsh. A few dominant species occupied each of these classes, making interpretation easier. Agricultural sites (Fig. 1) consisted of corn (Zea maze) and soybean (Glycine max). The second class, maritime forest (Fig. 1), was occupied by live oak (Quercus virginiana) loblolly pine (Pinus teada), laurel oak (Quercus laurifolia), red maple (Acer rubrum), sweetgum (Liquidambar styraciflua) and pignut hickory (Carya globra). Finally, marsh sites (Fig. 1) consisted of black needlerush (Juncus roemerianus), giant cordgrass (Spartina cynosuriodes) and common cattail (Typha latifolia). Seventeen sites were originally observed to gain a better understanding of the vegetational types present in the study area. Sites 1, 3, and 5 (Fig. 1) were chosen as control sites.

The second part of the investigation concentrated on preparation of a vegetation map of Perquimans County and comparison of the map with other published information. Heavy cloud cover over most of the region at the

time of the SKYLAB limited the choice of the test site. Perquimans County lies near the center of the cloud-free area north of Albemarle Sound, on Frame 30, Roll 27. (See also Fig. 1). The test site was mapped using the following broad land-use categories: agricultural, non-agricultural and forest. These categories were then further divided into types. Agricultural types chosen were corn, soybean, cleared (plowed) and pasture or old field. Non-agricultural types were residential or commercial and cleared areas. The third category, forest, was divided into conifers, hardwood, and mixed.

The mapping technique consisted of selecting the area of interest on 9-inch by 9-inch color and color infrared transparencies enlarged from 70 millimeter S190A positive transparencies. The color photography (Roll 28, Frame 29-31) was used specifically for ground references points (roads, buildings, etc.). This film had nearly twice the resolution of color infrared film. Welch (1974) using a microdenstometer edge trace with graphical and digital techniques estimated resolution on the color to be 85 meters and color infrared film to be 145 meters for the S190A experiment.

The imagery was studied utilizing a 70 mm squares cut from the enlarged S190A transparencies which were projected on to the viewing screen of a Spectral Data Model 66 color additive viewer. Also the imagery was projected on to a vertical, clear glass panel with frosted acetate mounted on it through the external projection mode of the viewer. Additional interpretation was made by study of the imagery with a stereo binocular microscope.

Ground verification was made at twelve sites within Perquimans County. The sites are shown on Figure 2. Simple spot checks were made at seven sites. These were small areas for which the interpreter questioned the identification

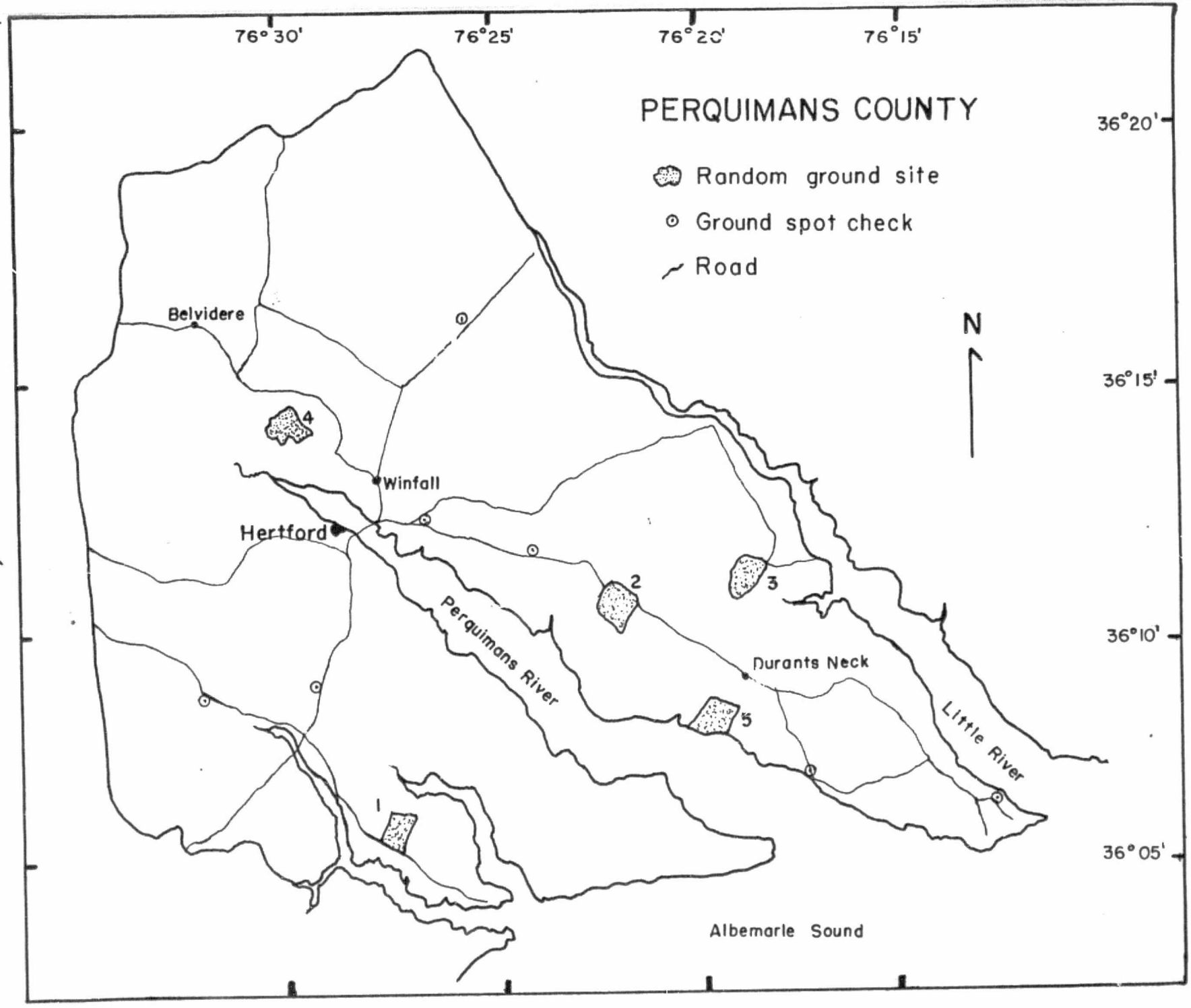

Figure 2. Ground verification sites in Perquimans county

from the imagery. The five other sites, each having an area of about one square mile, were analyzed in detail. The five test sites were chosen by using a five-place random number table combined with a grid overlay of the county at an appropriate scale. Each pair of numbers in the random number set was used to define the position of the test site. The first pair of digits was used to determine the row and the second the columns within the grid system. Field checks were made of the test sites and errors of interpretation determined. In addition to the field checks, U-2 photography (Flight Mission 73-185) taken two months after the SKYLAB mission was used to evaluate the accuracy of the vegetation map.

Discussion

Coastal Region

The major drawback in this study of the coastal vegetation was the extensive cloud cover over northeastern North Carolina. Only about 25 percent of this region could be used for interpretation purposes. Dare and Perquimans Counties (Fig. 1) had the least amount of cloud cover. The vegetation map was constructed for Perquimans County because only 18.5 percent cloud cover existed over the entire county.

Comparison with ERTS

The SKYLAB 3 photography was compared to ERTS imagery of the northeastern region. Plate 1 shows ERTS imagery and can be compared with Plate 2, the SKYLAB photography. Resolution appears to be better in the SKYLAB photography,

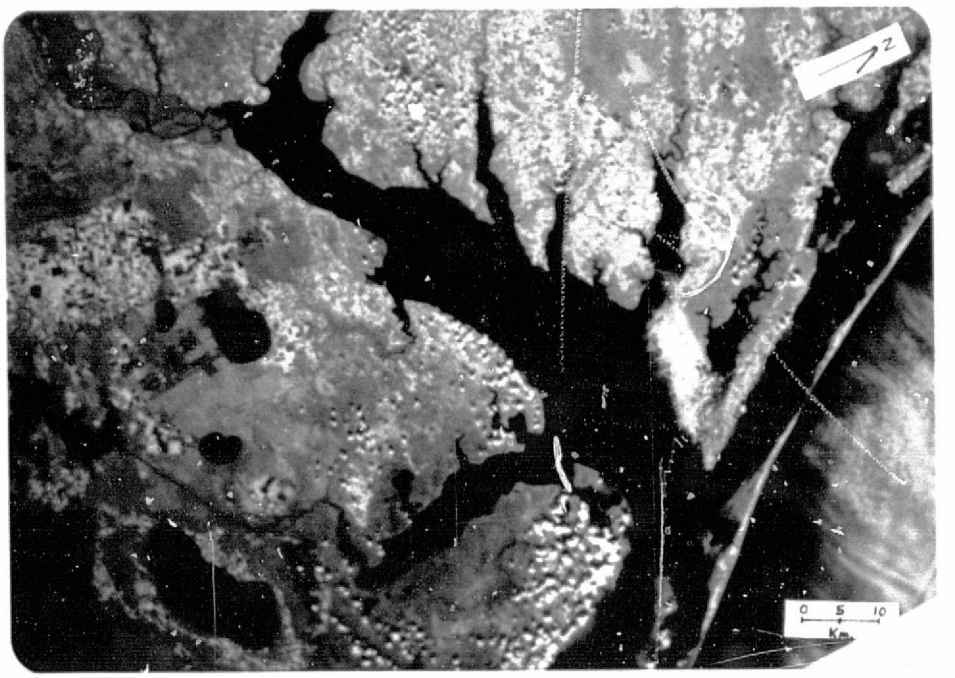

Plate 1. ERTS Image of Study Area.

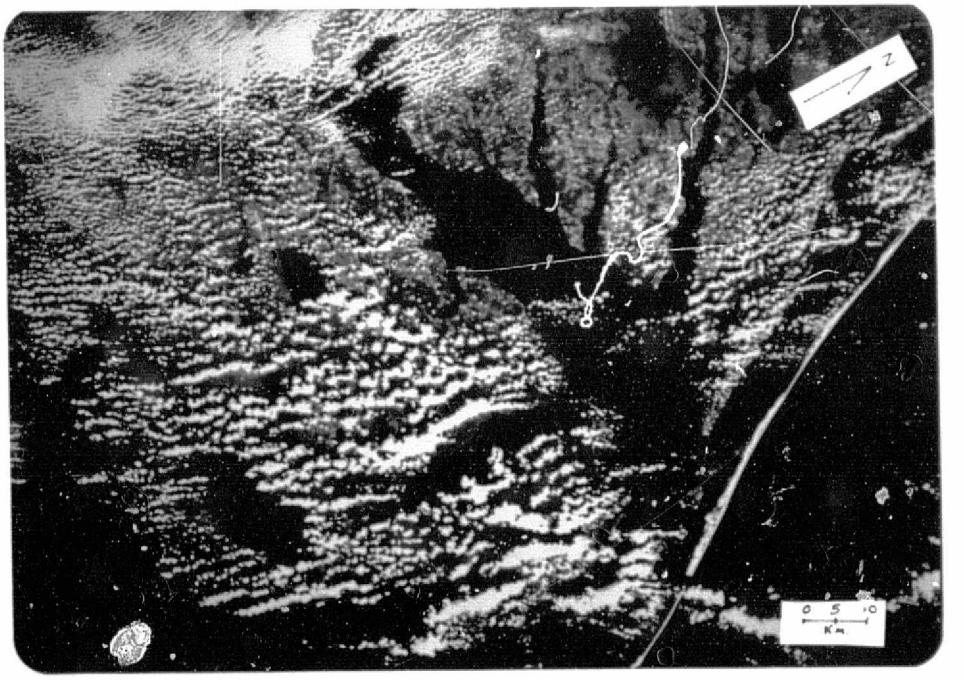

Plate 2. SKYLAB Photograph of Study Area.

a fact most easily explained on the basis of the difference in the method of data acquisition (SKYLAB photography vs electronic scanning). An interpreter can recognize vegetational differences easily on the SKYLAB film. Even when the ERTS imagery was observed with the aid of a color additive viewer, the vegetational differences did not appear to be as well defined as on the SKYLAB imagery.

Control Sites and Ground Studies

Ground studies were conducted at the three control sites (1,3,5) to familiarize the interpreter with zonation patterns and color tones transmitted by the species existing there. The zonation patterns established from the ground studies were useful in providing the interpreter with an idea of what species should and should not be present in similar sites. Color tone varied within vegetation classes and usually was the key to species identification.

Resolution

The interpretations were conducted under a stereo binocular microscope at 20X magnification. At greater magnifications color tones could not be interpreted adequately because the grain of the film scattered the light and made identification of a specific color difficult. Welch (1974) evaluated the SKYLAB photography and concluded that resolution estimates were 20 percent below expected values for color infrared images. He estimated that ground resolution should be 145 meters. Resolution of targets, wooded strips in the

forest category, had the best contrast and was determined to be 58-70 meters by ocular and graphical techniques with further magnification resulting in problems with the film grain.

Plant Signature With Color I.R.

This part of the investigation was conducted using SKYLAB 3 photography taken on 9 August 1973. The agricultural class mainly consisted of two crops, corn (Zea maze) and soybean (Glycine max). Both crops transmitted quite distinct colors. Zea sp. transmitted a bright red while the color tone from Glycine sp. was a scattered pattern of blue, red and white. Forest vegetation could only be recognized as conifers and hardwoods. Conifers appear as violet to dark purple, and hardwoods are a dark red color on the photographs. Finally, two dominant marsh species were identified. These were black needlerush (Juncus roemerianus), transmitting a medium blue color and giant cordgrass (Spartina cynosuroides) appearing medium red. Juncus sp. could be differentiated from water because of the medium blue of the former contrasted with dark blue to black of the water. A summary of the species encountered in the sites is given in Table 1.

Major Vegetation Sites

The agricultural sites were located around Elizabeth City in Pasquotank County, which borders Perquimans County on the east. Plate 3 is a copy of a color infrared image of the experimental site interpreted from SKYLAB photographs (Site 2) in Fig. 1). One problem existed in obtaining ground studies

of this unnatural vegetation class. Each year the crops were harvested and replanted with a different species. Fortunately, most of the rotation was between Zea maze and Glycine max. The retired Pasquotank County chairman of the Agricultural Extension Service, Mr. S. L. Lowery, assisted in the determination of the previous year's crop. Experimental site 2 was estimated to be 37 percent Zea sp., 51 percent Glycine sp., and 13 percent old field.

Interpretation of the old fields encountered some difficulties. The transmitted color tone was very similar to Glycine sp., being a scattered pattern of blue, red and white. There was no difficulty in determining Zea sp., from Glycine sp.

TABLE 1

Species List of Dominant and Minor Vegetation
Identified in the Ground Study Sites

Major

Pinus taeda - loblolly pine

Quercus virginiana - live oak

Taxodium distichum - baldcypress

Juncus roemerianus - black needlerush

Spartina cynosuroides - giant cordgrass

Zea maze - corn

Glycine max - soybean

Minor

Quercus laurifolia - laurel oak

Acer rubrum - red maple

Liquidambar styraciflua - sweetgum

Carya globra - pignut hickory

Pinus sertotina - pond pine

Chamaecyparis throides - Atlantic white cedar

Ilex opaca - American holly

Cornus florida - flowering dogwood

Fagus grandifolia - American beech

Nyssa aquatica - tupelo gum

Nyssa sylvatica - swamp tupelo

Arundinaria gigantea - giant cane

Typha latifolia - common cattail

Phragmites communis - marsh reed

Iva frutescens - marsh elder

Baccharis halimifolia - groundsel tree

Accuracy of identification was concluded to be 87 percent based on comparison with the ground truth information. A review of the interpretation revealed a slight signature difference between the old field and Glycine sp. types, but a difference that is difficult to recognize. The mixture of the three colors was mostly red and white with small amounts of blue present in the old field zone; in contrast the mixture for Glycine sp. was mostly red and blue with less white.

Maritime forest, sites 3 and 4 on Fig. 1, were located in Dare County near Kitty Hawk. Plate 4 shows a SKYLAB color infrared photograph of experimental

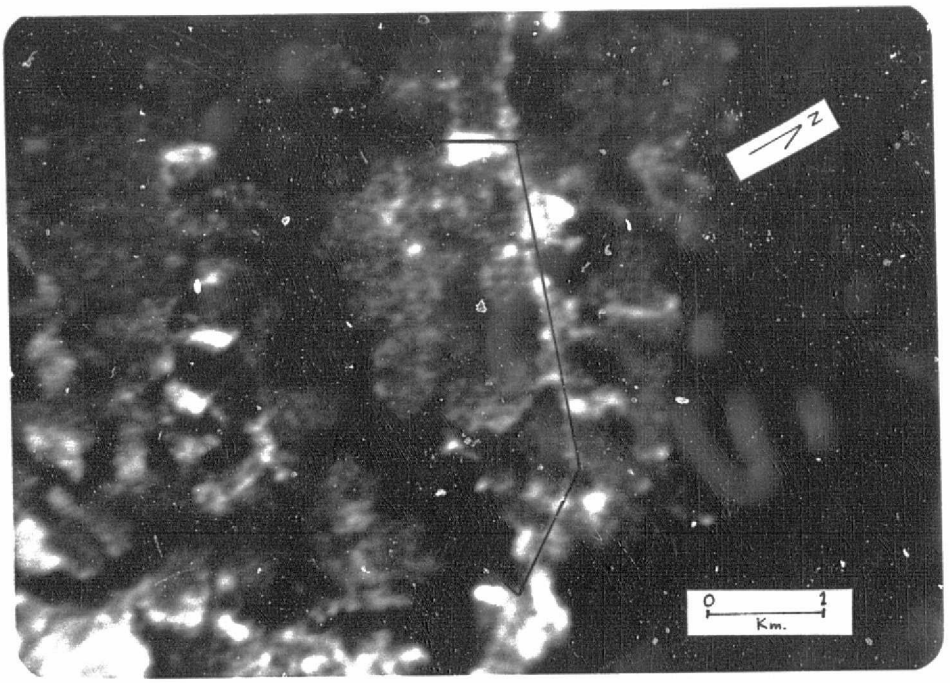

Plate 3. Agricultural Site 2.

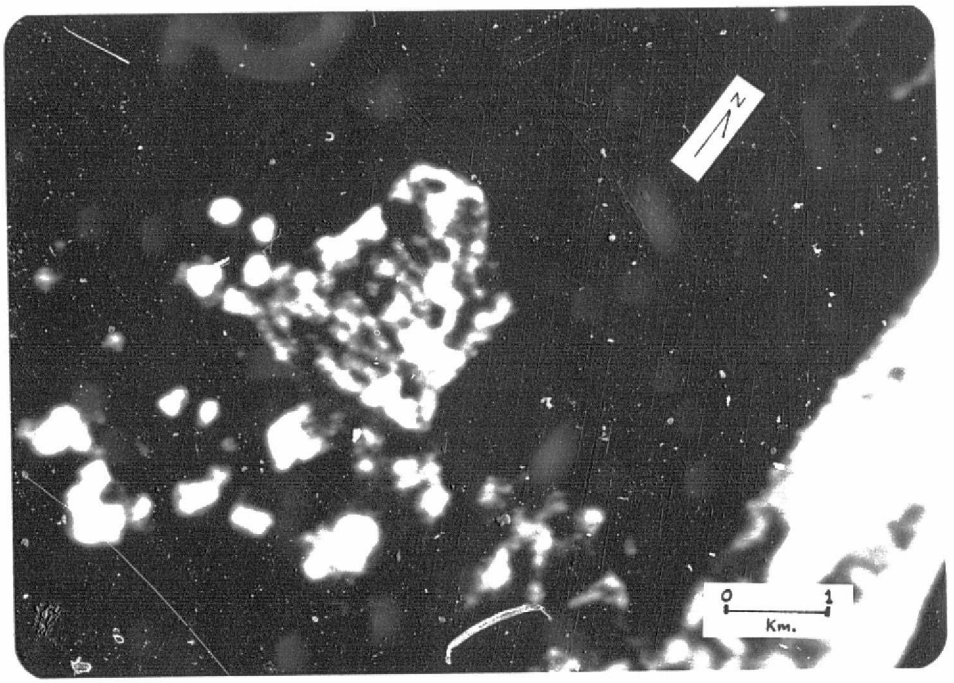

Plate 4. Maritime Forest Site 4.

site 4. Specific species could not be determined. Differences between dominant stands of hardwoods and conifers only were established. Experimental site 4 was determined to be 85 percent hardwoods and 15 percent conifers by weight apportioning and grid overlay methods. Loblolly pine (Pinus taeda) was the dominant conifer while live oak (Quercus virginiana) was the dominant hardwood. Most of the other species encountered were hardwoods. Accuracy was considered to be 100 percent because the dominant type was easily established.

Marsh test sites were located in Dare County around Roanoke Island. Plate 5 shows a SKYLAB color infrared photograph of the experimental site 6. Irregularly flooded salt marshes typify this area (Wilson, 1962). Salt marsh is an ideal vegetation class because few species survive in this harsh environment. The experimental site was determined to be 75 percent needlerush (Juncus roemerimum), 21 percent giant cordgrass (Spartina cynosuroides) and 4 percent common cattail (Typha latifolia). Two other minor species were identified as marsh shrubs.

Problems were encountered with the interpretation of Typha sp. Color tone of the albedo was the same as for Spartina sp. Both species show a medium red color. There was no difficulty in separating Juncus sp. from Spartina sp. because of the greater albedo which probably results from the more horizontal leaf angle and greater height of Spartina sp. Accuracy was concluded to be 96 percent because Typha sp. could not be separated from Spartina sp.

Vegetation Map

A vegetation map was constructed from color and color infrared photographs of Perquimans County, North Carolina. Color (Roll 28, Frame 30) and color

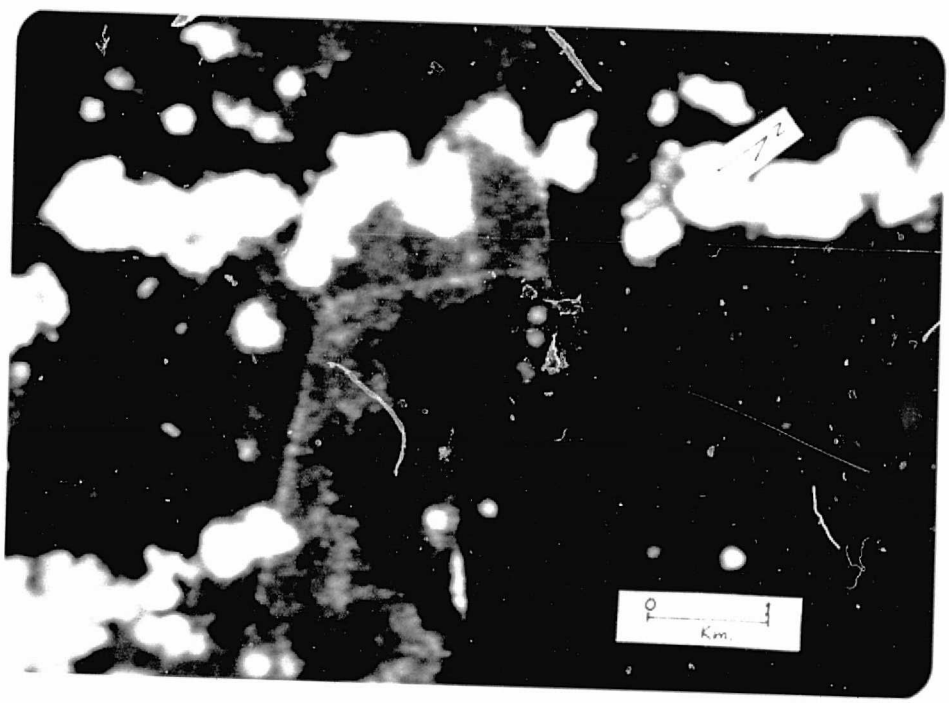

Plate 5. Marsh Site 6.

infrared (Roll 27 Frame 30) photographs of this area may be compared in Plates 6 and 7. Infrared imagery was found to be ideal for this type of interpretation, and color imagery was used mainly for establishing cultural ground reference points. Cloud cover of 18.5 percent prevented mapping of the entire county. Fig. 3 is the completed vegetation map of Perquimans County.

One problem encountered during the mapping was in differentiating between soybean (Glycina max), and old field and pastures in some areas. Interpretation accuracy was evaluated through two approaches.

Color infrared photography taken during a U-2 flight in November, 1973 (Flight 73-185) provided general data for checking the SKYLAB imagery. At this time of the year most of the agricultural crops had been harvested and fields plowed, although some crops still persisted; fields and forest vegetation could be readily verified. There seemed to be a good correlation between the vegetation map and the U-2 imagery.

Ground verification at the five randomly chosen sites, provided specific data for checking SKYLAB photography. Location of these sites is noted on Figure 2, and each site has an area of approximately one square mile.

Random ground site 1 is located six miles due south of Hertford, the approximate center of Perquimans County. This site was determined to be 6.3 percent conifer and 43.9 percent mixed of the forest category. Agricultural elements were 35.4 percent corn, 4 percent soybean, 6.1 percent old field and 4.3 percent pasture. An error reduced the interpretation accuracy to 89.6 because old field, pasture and soybean could not be separated clearly on the SKYLAB photography.

The location of random ground site 2 is 6 miles southeast of Hertford. Forests consisted of 27.2 percent mixed. The agricultural division was 38.4

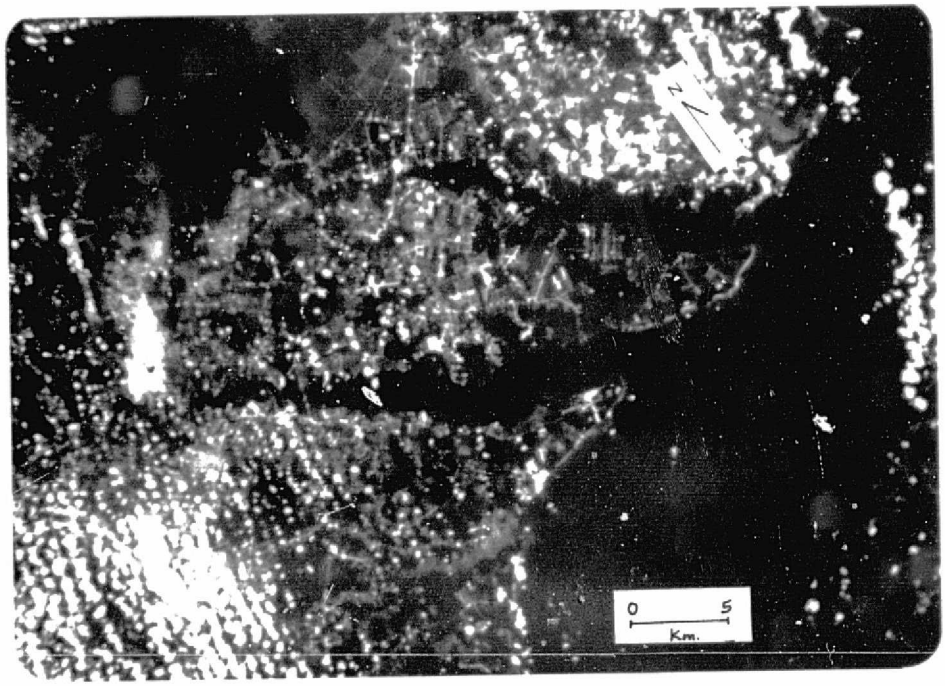

Plate 6. Color Photograph of Perquimans County.

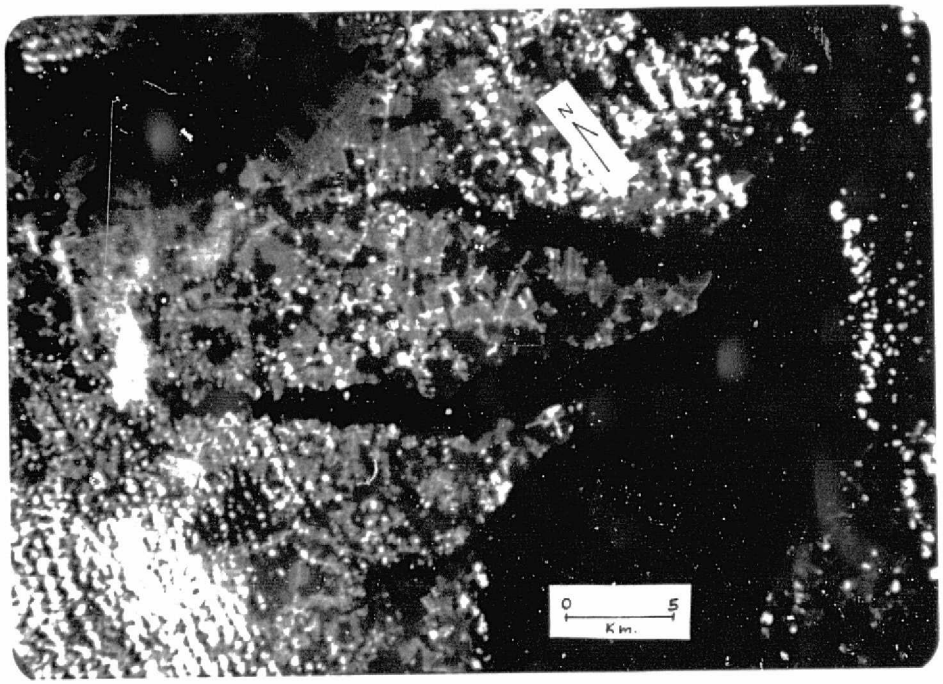

Plate 7. Color I.R. Photograph of Perquimans County.

VEGETATION MAP
PERQUIMANS COUNTY
SKYLAB 3 DATA
AUG. 9,1973

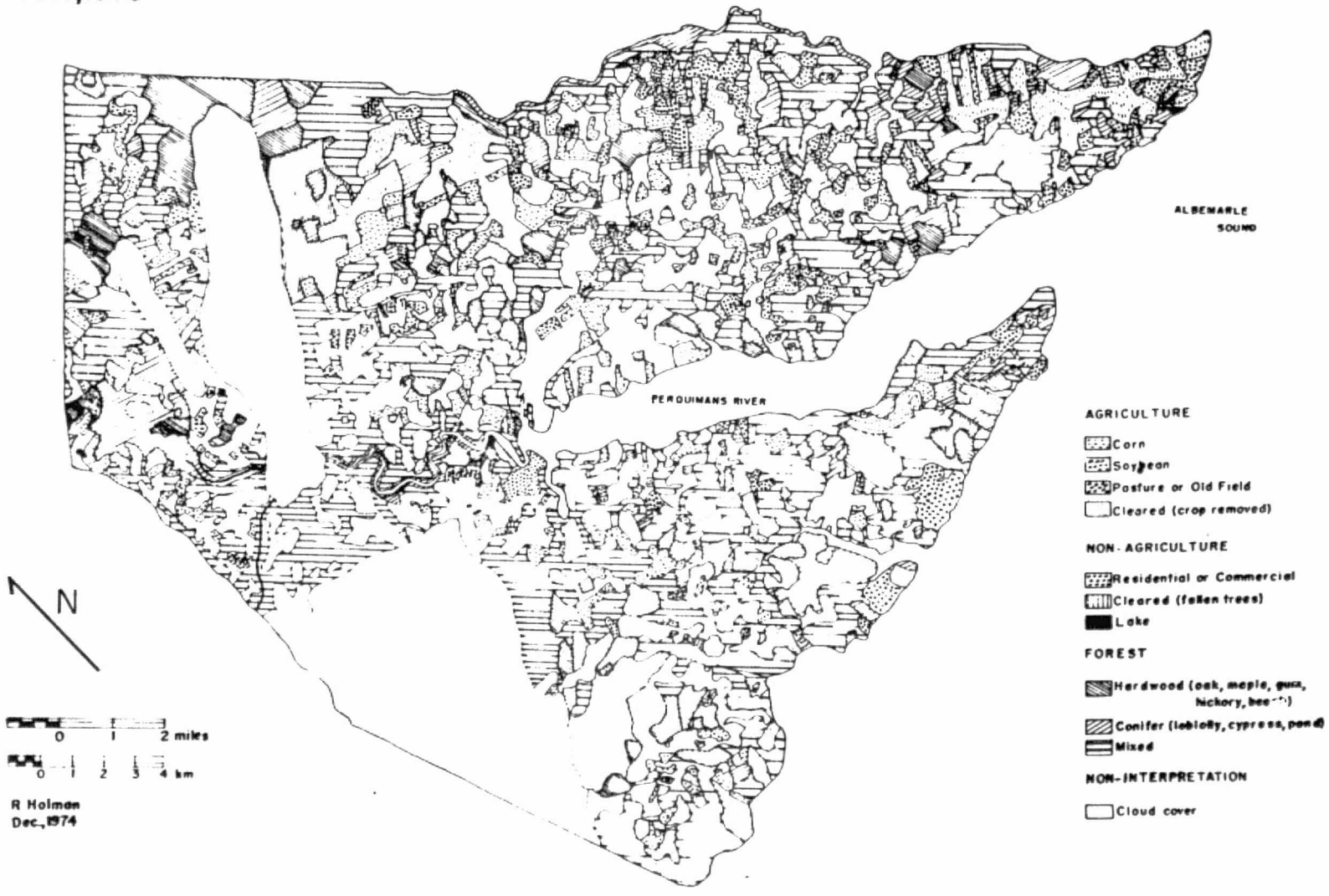

Figure 3

percent corn and 34.4 percent soybean. Cloud cover obscured about 7 percent of the site. The accuracy of interpretation of the cloud free areas was 100 percent.

Random ground site 3 is located 8 miles southwest of Hertford. The forest category was 18.1 percent conifer and 36 percent mixed. Agricultural division consisted of 22 percent corn and 24 percent soybean. Corn could not be distinguished from a young pine plantation because giant cane whose signature resembled the corn was growing between the young pines, (Arundinaria gigantea) modifying the apparent signature of the young pines. The extent of the modification was such that the combined pines and cane areas could not be easily distinguished from a like area of corn. The same height of pine and cane (eight feet) combined with the similar leaf angle of cane and corn made it impossible to distinguish corn from the young pine plantation. The interpretation accuracy for this site was 84.5 percent.

Random ground site 3 is located 3 miles northwest of Hertford. This site was made up of 12 percent hardwood and 54 percent mixed of the forest division. The agricultural category was 30 percent corn and 4 percent soybean. A minor error attributed to cloud cover made the interpretation accuracy 92.4 percent.

Random ground site 5 is located 7 miles southeast of Hertford. Forests consisted of 34.7 conifer and 29.6 mixed. Two elements were found in the agricultural category. These were 5.5 percent cleared and 5 percent soybean. Problems were encountered in interpreting wooded swamps. These regions produced a dark reflectance similar to conifers and are easily mistaken for conifer stands when a mixed stand of hardwoods (Nyssa aquatica and Nyssa sylvatica) and conifer (Taxodium distichum) actually exist. For the imagery

used the explanation lies in part at least in the presence of the trees. The water reduces the reflectance. Accuracy of interpretation for this test site was 94.6 percent.

Interpretation accuracy for all the random ground sites varied between 84.5 and 100 percent. The two largest errors were caused by cloud cover and by the presence of giant cane between trees on a young pine plantation.

A comparison of SKYLAB interpretative results with statistics obtained from the North Carolina Department of Agriculture was made. Vegetational types were mainly defined in the SKYLAB photography by color tone association. Areas with the same color tone were combined to obtain a percentage for particular vegetation type. Acreage totals were compiled by the North Carolina Department of Agriculture from Farm Census Supervisors and Township Listers. A summary of the information obtained from both sources is given in Table 2. The major drawback in comparison of the two sources was that different components were included and omitted in the same major categories.

A review of the forest category revealed that both estimates were similar (36 percent). No further division of this category was conducted by the State Agriculture Department.

TABLE 2

A Comparison of Crop Statistics of Skylab and North Carolina Department of Agriculture

	Category	Agriculture Dept.			Skylab
A.	Agricultural	(harvested)	36.0%	(total farm land)	42.2%
	1. soybean		20.2%		11.6%
	2. corn		11.9%		27.5%
	3. peanuts		2.2%		-- *
	4. pasture		2.0%		2.1%
	5. other grains		1.7%		-- *
B.	Non-agricultural (no agricultural production)		26.0%		3.8%
	1. residential or commercial		----		2.2%
	2. cleared		----		1.6%
C.	Forest		36.0%		35.4%
	1. conifers		----		12.4%
	2. hardwoods		----		6.8%
	3. mixed		----		16.2%
				*(cloud cover)	18.5%
		Total	100%		100%

* 18.5% of the county was covered by clouds over area where peanuts and other grains were concentrated.

The non-agricultural category showed the largest discrepancy. Residential and commercial areas were only included in the SKYLAB interpretation (3.8 percent) while areas of no significant agricultural production (26 percent) were included in the State Agriculture Department's figures. The 22.2 percent difference can be almost any other type of land use other than agricultural in the state figures.

The interpretation of the SKYLAB photographs gave a higher percentage (42.2 percent) of land devoted to agriculture than did the Department of Agriculture figures (36 percent). This difference is attributed to the fact that the state estimates were for harvested crops while SKYLAB figures were on standing crops. The percentage of the Pasture Category mapped from the SKYLAB data agreed in general with the state's estimate (2 percent). Peanuts and grain crops were not included in the SKYLAB figures because the northwestern part of the county in which these crops are concentrated, was cloaked with cloud cover. The areas hidden below the clouds were later interpreted by U-2 photography to be around 25 percent forest and 75 percent agricultural, indicating the standing crop should be larger than the figures given in Table 2. Soybean and corn percentages from the SKYLAB imagery and from the Department of Agriculture data did not agree. SKYLAB percentages for corn were 27.5 percent and 11.6 percent respectively; the corresponding figures from state data are 11.9 and 20.2 percent. These differences may be due to the error arising from misidentification of young pine plantations. On the other hand, the ground verification of SKYLAB interpretations which separated corn from soybeans showed the interpretation to have an accuracy of 100 percent. It is possible that SKYLAB-type imagery can be used to obtain more accurate acreage values for these two crops in North Carolina than is possible by present methods.

Conclusions

Color infrared photography from SKYLAB 3 appeared to be superior to ERTS imagery in a vegetational study of northeastern North Carolina. An accuracy of 87 percent was achieved in delimiting species composition and zonation patterns of three coastal, vegetation classes. A vegetation map of Perquimans County, North Carolina, seemed to have a high degree of correlation with information provided by high altitude U-2 photography. Random verification sites revealed an overall interpretation accuracy above 84 percent.

Comparison of maps drawn utilizing SKYLAB photography with North Carolina Department of Agriculture estimates of crop acreage revealed some marked discrepancies. The chief difference lies in the non-agricultural category in which there is a 30 percent discrepancy. This fact raised some questions as to the definition of non-agricultural land uses and methods used by the State Department of Agriculture to determine actual percentages of crops grown.

Two difficulties were encountered in using SKYLAB photography. Cloud cover limited the area available for study, and a number of possible study sites were either eliminated or restricted in area by the cloud cover. Ocular and graphical techniques revealed a resolution of 58 to 70 meters. Resolution was lower in this study than other uncited studies because of limitations placed on estimating the actual extent of the vegetation zone by film grain.

Other methods of estimating land uses and the boundaries between land uses should be compared with remote sensing means for an added perspective and possibly increased accuracy in final interpretation. Large areas can be viewed in one image with the space-acquired imagery, and differences can be more easily recognized than from low altitude and ground level studies alone.

Benefit-Cost Ratio

Vegetational analysis can be accomplished within a week's time, after sufficient ground data is provided for a particular county. The speed of interpretation depends on the familiarity the interpreter has with the area in question, and it can be reasonably assumed that if repetitive imagery were available to a person familiar with an area the information could be extracted in only a day or so.

Perquimans County has a rather low population density, and changes in the agricultural category would probably be the most significant in terms of numbers and area. These changes would represent crop rotation chiefly. Future expansion will probably be made in the croplands as forested areas are cleared and converted to seasonal crops. It can also be expected that there will be population increases in the future, but they will be at a much slower rate than the agricultural expansion and changes.

One major benefit demonstrated by this study is that the State Agricultural Department could keep more up-to-date and accurate records of crop yield, expansion and potential problem areas through the use of space-acquired imagery. As the investigators have no way of assessing the man-hours required to gather and tabulate the acreage figures for the various crops, they cannot provide an accurate benefit-cost evaluation. However, for an area such as Perquimans County the ability to gather needed crop statistics on the part of an Agricultural Department employee in a matter of a day or so could be an important benefit in administering various agricultural programs. Space-acquired imagery could save many of the man-hours involved in mailing out questionnaires, tabulating the answers, and in bringing the data and its interpretation to a central location for later disbursement. On the other hand, the turn-around-time for

acquisition of the space-acquired data is a handicap to its potential use.

A measure of the benefits, of course, is the importance attached by various agencies to crop inventories and the speed with which the data needs to be processed. If a need exists for essentially within-season crop inventories from northeastern North Carolina, space-acquired imagery at a scale comparable to that of SKYLAB on a repetitive basis should prove of considerable economic benefit. If knowledge of patterns of crop rotation is of economic importance, space-acquired imagery may be the least expensive, most accurate way to accumulate this information over a period of years. The images and pictures are a permanent record of what exists.

In either case a single county in northeastern North Carolina could probably be studied and mapped at a cost of two or three man-days with a light table, a binocular microscope and some suitable means of measuring areas on the photograph. Skill of the interpreter would control the accuracy of the determinations, but a skilled interpreter knowledgeable about the area could probably achieve a 90-95% or better accuracy. For some crop studies the rapid inventorying could be of considerable advantage.

Acknowledgments

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